

Improvements to the Hydrolight Radiative Transfer Model and Teaching at the 1998 Friday Harbor Optical Oceanography Course

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LONG-TERM GOAL

The goal of this work was to develop user-friendly, powerful radiative transfer software for research and teaching in optical oceanography. I believe that radiative transfer models are just as important a tool in optical oceanography as any instrument for measuring the optical properties of a water body.

OBJECTIVES

This work had the dual objectives of developing a version of my widely used HYDROLIGHT radiative transfer model that would run on personal computers (PCs) and then using the PC version as a core teaching tool in the University of Washington's 1998 summer course in optical oceanography.

APPROACH

Previous versions of the HYDROLIGHT radiative transfer code (Mobley, 1989; Mobley et al., 1993; Mobley 1995) have been widely used by academic and Navy researchers. However, the use of HYDROLIGHT required the user to be moderately proficient in FORTRAN and to have access to mainframe computers or UNIX workstations. This limited the usefulness of HYDROLIGHT, especially for classroom teaching. Numerous users therefore requested a more user-friendly version of HYDROLIGHT that would reduce the need for programming expertise and that would run on inexpensive PCs. In particular, users requested a Graphical User Interface (GUI) for the model and the option to analyze the output with spreadsheets.

Various languages for writing a GUI were evaluated, as was commercial-off-the-shelf graphical and spreadsheet software for analyzing HYDROLIGHT output. Because most users wish to run HYDROLIGHT on a PC with a Microsoft Windows operating system, Microsoft Visual Basic was selected for writing the GUI, and Microsoft Excel was selected as the spreadsheet of choice for analysis of output.

WORK COMPLETED

The available funding sufficed to develop a simple GUI front-end program for HYDROLIGHT and to develop macros that would convert selected HYDROLIGHT output files into Excel spreadsheets (and to cover my time for teaching the Friday Harbor summer course). However, rather than stop at this point, I decided to invest additional time and funds to further develop the GUI and to make a major rewrite of the HYDROLIGHT code itself. The resulting software package, HYDROLIGHT Version

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4.0, was used as an important teaching and data analysis tool during the University of Washington's summer course in Optical Oceanography, which was taught at Friday Harbor, Washington, 20 July to 22 August 1998.

Some of the specific improvements made to HYDROLIGHT in developing Version 4.0 are as follows:

- Two front-end programs were developed. The GUI front end runs on PCs with Microsoft Windows 95/98/NT operating systems. Figure 1 shows examples of the GUI forms that are filled out by a user when making a HYDROLIGHT run. A text-based "question-and-answer" front end program runs on other operating systems. These front-end programs automate many of the tasks of creating input files, running HYDROLIGHT, and managing the output files generated by a HYDROLIGHT run.
- It is now much easier for users to write their own models for inherent optical properties or to use empirical data as input to HYDROLIGHT. For example, users can now read WETLabs ac-9 (or similar) data directly into HYDROLIGHT, after placing the data on a standard format (see Fig. 1).
- The HYDROLIGHT core code was rewritten to use public-domain software for common mathematical tasks such as solving differential equations and inverting matrices. This means that users no longer need to purchase expensive commercial mathematics packages in order to run HYDROLIGHT.
- Some of the internal algorithms were changed, with the result that HYDROLIGHT 4.0 runs as much as three times faster than version 3.0.
- Additional output files are written. These files are designed for conversion into Excel workbooks by Excel macros, which are a part of the HYDROLIGHT software package. Users can then analyze HYDROLIGHT output and generate simple graphs using Excel.

In addition to the above improvements to the HYDROLIGHT code, the students at the Friday Harbor summer course were trained in the use of HYDROLIGHT as a tool for data analysis and prediction.

I gave eight lectures at Friday Harbor as a part of the teaching component of this contract. The lectures covered a wide range of topics, e.g., "Measurement of Scattering," "Ocean Color Remote Sensing," "Lidar Bathymetry," and "Polarization."

RESULTS

HYDROLIGHT Version 4.0 was well received and well tested by the students at the Friday Harbor summer course (Mobley, 1999). They made many valuable suggestions for further improvements, which already have been incorporated into the software. HYDROLIGHT was a foundation of many student research projects. A special session will be held at the American Society of Limnology and Oceanography 1999 Aquatic Sciences Meeting in Santa Fe to describe these student projects and HYDROLIGHT's role in the summer course.

IMPACT/APPLICATIONS

HYDROLIGHT Version 3 has been used by approximately 60 investigators including U.S. and foreign academics and scientists at U.S. Navy research laboratories. Version 4.0 likely will be even more popular because of the ease of its use and increased capabilities.

TRANSITIONS

Beta-test versions of HYDROLIGHT 4.0 have been delivered to the Naval Research Laboratory, to the U.S. Naval Academy, and to several academic and commercial investigators, pending release of the final product, which is scheduled for 30 October 1998.

The initial GUI and other code developed under this project were transitioned to Sequoia Scientific, Inc. for further development into a commercial product. It is hoped that the commercial sales of HYDROLIGHT 4.0 will both repay the unfunded development costs and finance future improvements in this powerful software package. The latest version of HYDROLIGHT is described in Mobley (1998a, 1998b) and at <http://www.sequoiasci.com/hydrolight.html>.

RELATED PROJECTS

The first use of HYDROLIGHT 4.0 was as a teaching tool during the University of Washington summer course in Optical Oceanography (Mobley, 1999a). That course is described in a separate report filed by Dr. Mary Jane Perry.

Version 4.0 is being used by the author in separately funded ONR research on the effects of microbial particles on oceanic light fields and on the effects of bottom boundaries on oceanic light fields. The projects are described in separate annual reports.

A special version of HYDROLIGHT 4.0 designed for incorporation into coupled biological-optical-physical ecosystem models will be developed under the ONR HyCODE program.

REFERENCES

Mobley, C.D., 1989. A numerical model for the computation of radiance distributions in natural waters with wind-roughened surfaces. *Limnol. Oceanogr.* 34(8), 1473-1483.

Mobley, C.D., 1995. Hydrolight 3.0 Users' Guide. Final Report, Project 5632, SRI International, Menlo Park, CA, 65 pp.

Mobley, C.D., 1998a. Hydrolight 4.0 Users' Guide. Sequoia Scientific, Inc., Mercer Island, WA, in preparation.

Mobley, C.D., 1998b. Fast calculations in radiative transfer theory. Invited talk to be given at Ocean Optics XIV, Nov.10-13, Kona, HI.

Mobley, C.D, B. Gentili, H.R. Gordon, Z. Jin, G.W. Kattawar, A. Morel, P. Reinersman, K. Stamnes,

and R.H. Stavn, 1993. Comparison of numerical models for computing underwater light fields. *Appl. Optics* 32(36) 7484-7504.

Mobley, C.D., 1999. Intensively learning optical oceanography: Hydrolight in the classroom. Poster to be presented, Am. Soc. Limnol. Oceanogr. Aquatic Sciences Meeting, Feb. 1-5, Santa Fe, NM.

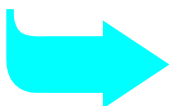
HYDROLIGHT

Inherent Optical Property Specification

Select the "ab" routine that will be used to specify the absorption coefficient (a) and scattering coefficient (b) as functions of depth and wavelength:

- ☐ ABCONST: a and b are independent of depth (single-wavelength runs only)
- ☐ ABCASE1: a and b are obtained from bio-optical models for Case 1 water
- ☒ ABAC9: a and b are obtained from a USER-SUPPLIED file of ac-9 data
- ☐ OTHER: a and b are obtained from a USER-SUPPLIED model

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HYDROLIGHT

ABAC9 is a two-component IOP model

Component 1 is pure water

Component 2 is 'everything else' (chlorophyll-bearing particles, CDOM, etc.; a and b=c-a will be obtained from a file of ac-9 data). The file containing the phase function for Component 2 is

Routine abac9 will call a USER-SUPPLIED file containing HYDROLIGHT STANDARD-FORMAT ac-9 data. Enter the name of the data file (including the path, if the file is not in the ..\data directory):

Back **Continue**

Figure 1. Examples of the GUI forms that are filled out when making a HYDROLIGHT 4.0 run. In the top form, the user selects the type of model to use for the inherent optical properties of the water body. In this example, ac-9 data will be used to obtain the absorption and scattering coefficients. The bottom form shows the information needed for the use of ac-9 data. About ten such forms are required to specify all of the input needed for a HYDROLIGHT run.